Applied Geography 90 (2018) 350–359

Contents lists available at ScienceDirect

Applied Geography

journal homepage: www.elsevier.com/locate/apgeog

Responses to stimulate substitution and cascade use of wood within a wood use system: Experience from Bavaria, Germany

Gordon M. Winder*, Amra Bobar

Economic Geography, LMU Munich, Germany

ARTICLE INFO

Article history:
Received 3 July 2016
Accepted 9 September 2016
Available online 4 October 2016

ABSTRACT

The ideas of cascade use within the wood use system and innovation of new wood-based materials and applications to substitute for other materials have recently gained new impulse within Germany since they have been declared to be priorities within the German government's climate change related policies. This paper explores responses to government policies for a sustainability transition through more intensive and efficient use of wood among Bavarian enterprises. It is based upon interviews with architects, officials, and enterprise owners and managers conducted in 2015 and 2016. The research identifies the opportunities for and barriers to substitution and cascade use of wood as perceived by managers of enterprises embedded in the wood use system. The paper assesses whether the enterprises studied are ready to be change agents in the envisioned sustainability transition. It also maps out the complex Bavarian institutional context within which innovative uses of wood are taking place.

1. Introduction

The United Nations Framework Convention on Climate Change (UNFCCC), which was negotiated at the Earth Summit in Rio in 1992, emphasizes that forests are crucial for mitigating climate change. Forests store carbon in both the forest soil and in the trees' wood, and wood can be considered to be "climate-neutral," in the sense of potentially releasing only as much carbon as it has initially stored (while assuming a constant regrowth of trees). When wood is harvested carbon is transferred from forests to products, and wood products with particularly long lives lock-in stored carbon and prevent its release into the atmosphere as CO_2. With its multiple roles as a carbon stock, a versatile material and as renewable energy source, wood can contribute to the reduction of greenhouse gas emissions and therefore plays an important role in the discussion of climate change mitigation (Gustavsson et al. 2006; Werner, Taverna, Hofer, Thuerig, & Kaufmann, 2010). In this paper, attention is especially given to the reduction of CO_2 emissions through the substitution of wood for more energy-intensive materials and construction methods as well as for fossil fuels (Werner et al. 2010). Although the distinction between fresh forest biomass and recovered wood and fiber is analytically useful when examining the role of wood for reducing net greenhouse gas emissions (Gustavsson et al. 2006), it is also crucial because wood resources are not infinite and the availability of fresh wood material is limited, so that it is important to use it efficiently (Sathre & Gustavsson, 2006).

Cascade use or cascading is a prominent approach for optimizing resource utilization (Dammer et al. 2016; Haberl & Geissler, 2000; Sathre & Gustavsson, 2006; Sirkin & ten Houten, 1994). Cascade use is defined as "the use of the same unit of a resource in multiple successional applications" (Höglmeier, Steubing, Weber-Blaschke, & Richter, 2015) and means "to use raw materials such as wood, or other biomass […] as long, often and efficiently as possible for materials and only to recover energy from them at the end of the product life cycle." (Dammer et al. 2016). Cascading and substitution of wood are two connected strategies, which cannot be separated, since substitution effects are especially important when the demand for energy and carbon intensive non-wood materials is reduced through cascading.

Research on cascading and substitution mainly takes the form of regional case studies which feature the modelling of material-flows and scenario-based work in order to assess the reduction of greenhouse gas emissions as well as energy and carbon balances. Both strategies are entangled, but, depending on the scope of research, some work focuses more on substitution (Gustavsson et al. 2006; Petersen & Solberg, 2005; Werner et al. 2010), while other work emphasizes cascading (Haberl & Geissler, 2000;

* Corresponding author.
E-mail address: gordon.winder@lmu.de (G.M. Winder).

http://dx.doi.org/10.1016/j.apgeog.2016.09.003
0143-6228/

Höglmeier et al. 2015; Sathre & Gustavsson, 2006; Sikkema, Junginger, McFarlane, & Faaij, 2013; Sirkin & ten Houten, 1994). Wood substitution and cascading effects are influenced by various factors, including quality and quantity of energy and material, technology and legislation (Gustavsson et al. 2006). They can be analyzed at different levels and with different approaches like life-cycle assessment and material and energy flow models. For example, the study by Höglmeier et al. (2015) combines a Life Cycle Assessment (LCA)-based material flow model of wood material and energy generation options based on the region of Bavaria in southeast Germany with an algebraic optimization tool to enable a systemic assessment where cascading utilization of wood is integrated and which could be transferred to other countries with similar wood utilization systems.

In contrast, research into responses of enterprises to the concept of cascade use of wood, and into already implemented cascade chains, is far less prominent. Therefore, our research, which is also based on Bavaria, investigates the possible implementation and likely implications of a cascade use and substitution of wood from an economic geography perspective. In this paper we focus on the perceptions of actors within the construction and the related waste management sector. We address the following general research question: How are substitution and cascading challenging practices within well-established industries? Economic geographers tend to research whether regions, clusters or enterprises are innovative, and they rarely step outside the frameworks of established industries, sectors or technology classes in their work on the geographies of innovation. To date, there has been little research directed by economic geographers to the effectiveness of regulatory interventions to promote desired environmental outcomes through changed material use, relative to, for instance, research on the effects of carbon offset regimes (Bumpus & Liverman, 2008; Knight, 2011; While, Jonas, & Gibbs, 2010), or barriers to the diffusion and uptake of new energy technologies (for example Davies & Mullin, 2011; Pasqualetti, 2011; Jepson, Brannstrom, & Persons, 2012), or geographies of innovation in bio-technology (Feldman 2003; Sæther, Isaksen, & Karlsen, 2011; König, Kohler, Kreissig, & Lützendorf, 2009; Buerger, Broekel, & Coad, 2012; Oort & Bosma, 2013; Qian, Acs, & Stough, 2013). Yet there is clearly a need to augment the modelling of material-flows and scenario-based work related to assessments of greenhouse gas emissions, energy and carbon balances with research on iterative learning in regions (Birch, 2009; Cooke, 2007), and industry responses to calls for cascading and substitution.

Our research agenda deals with opportunities and barriers to SME responses to calls for pro-environmental action. The relevant literature, recently summarized by Peter North (2016: 447–448), contrasts, on the one hand, owner's positive assessments of the opportunities and challenges of action, the minimizing of the costs of non-compliance, and ethical commitments particularly valorized in terms of the social license to trade, with, on the other hand, the "concrete realities" facing serious, practical, hard-headed SME owners, who tend to see government policies as contradictory and serving vested interests, who do not understand their own environmental impact, who are not prepared to make costly changes in business practices since they view consumers as uninterested in the environmental results, and who, in any case, lack the capacity, knowledge or enthusiasm to make the necessary changes. Nevertheless, North (2016: 450) reports that "SME owners do engage with a rich repertoire of pro-environment practices." He notes that this is usually interpreted in terms of some combination of their environmental vision, their embeddedness in local community and culture, their values, personal commitment, world view, belief system or confidence in their ability to make a difference. Catalytic change agents are seen as important to foster change.

This paper focuses on companies and experts involved in Bavaria's construction and waste wood industries. Since enterprises must put the concept into practice for cascade use to be effective, it is important to know how they understand the concept and whether they have considered it in their businesses. What do the managers of relevant enterprises perceive as the opportunities for and barriers to cascade use of wood and how is innovation defined within the wood use system? This paper focuses on enterprises that are already engaged with wood in construction and waste management. First, we discuss the methodology behind the research. The wood-related industries form a diverse, and well-established economic sector in Bavaria, where the Cluster Forest and Wood is actively promoting its work and postulated significance. Therefore, we are particularly interested in the complex Bavarian institutional context within which innovative uses of wood are expected and taking place. It is to this institutional context that we then turn, before elaborating the specific context of the Bavarian construction industry, including the range of measures that have been applied there to effect the transition. We then outline our results before concluding our findings.

2. Methods

From this methodology, it is not possible to tell precisely what effect the networking in Bavaria's construction industry will have on greenhouse gas emissions, and this is not the purpose of this paper. Necessarily, this study engages with the learning processes in firms, as they respond to stimuli from a range of policies and institutions. Since the information sought is qualitative, expert interviews were used. Our focus was on in-depth interviews with key-informants (owner-managers) in a variety of enterprises. Each interview took between one and 2 h, and included questions related to knowledge of cascade use and substitution as practices, their applicability to the enterprise, relations with business associations and industry institutions, and attitudes towards certification and regulation. Owner-manager self-assessments of the opportunities and barriers to cascade use and substitution were sought. In each case, the size, age and specialization of the enterprise was established so that the expert assessments given by those interviewed could be related to the character of their business.

The organization of the house construction industry is notoriously convoluted (Reiffenstein, Hayter, & Edgington, 2002). Diverse construction formats are possible including prefabrication on a large scale and customized production on site. Individual projects may be conducted at various scales ranging from renovations and repairs on parts of buildings through to large scale individual projects requiring the coordination of many subcontractors and enterprises in long and complicated production schedules. The design and coordination aspects of each project vary enormously, sometimes requiring more or less input from city planners, building inspectors, engineers, architects and other experts. Consequently, the industry continues to feature a diverse array of enterprises, specializations, and networking arrangements. This is an industry which features many small enterprises, some large companies, and both hand-, machine-, and automated machine-work. These features of the industry mean that it is important to interview experts from a range of enterprise types.

Interviews with construction companies were conducted by Michael Maier. He interviewed the manager of a large concern in Aichach, employing 200 workers (interview F, 09.12.2015) (Table 1). This firm was purchased by the large construction concern Züblin AG of Stuttgart in 2013, and specializes in timber products, and especially laminated timber beams. The owner-manager of a family firm established in Holzkirchen in 1920 (interview G, 23.11.2015) was interviewed. He employs 80 workers to complete 40–50

Table 1
Characteristics of the firms of the managers interviewed

Inter-view	Location	Year established	Employment (no.)	Ownership	Specialization
Architectural firms					
A	Gauting	1981	40	personal	public projects, especially schools; new to wood
B	Munich	1999	20	personal	rural projects, half of them in wood, including an energy plus school; trained as carpenter; taught at TUM
C	Munich	1989	10	personal	favors wood for small, private projects; not a wood specialist; has won prizes in wood, brick and concrete construction
D	Munich	1984	7	personal	specialist in sustainable construction; has leading projects in wood, including largest wood project in Munich; an initiator of the city's CO_2 Bonus program; teaches and advises on energy, ecology and economy
E	Augsburg	2003	4	personal	renovations, especially facades; mostly wood buildings; 12 years teaching at TUM; active with Holz Cluster Bayern
Construction firms					
F	Aichach	2011	200	corporate	Finished construction; large and international projects; wood engineering; laminated beams; since 2013 part of Züblin AG
G	Holzkirchen	1924	80	family	finished houses; highly insulated wooden houses
H	Leitzachtal	2011	4	personal	carpentry; distributor for Ehjösus Schwedenhäuser in Southern Bavaria; is a licensed Master Builder
Waste management firms					
I	Bad Feilnbach	2014	5	personal	recycled timber
J	Murnau	nd	nd	corporate	waste management; a branch of Veolia Environment SA
K	Munich	nd	120	corporate	waste management

Source: interview data.

finished houses per year. These houses feature high insulation ratings and his firm is heavily engaged with energy efficiency in housing. To widen the range of establishments, a further interview was conducted with the owner-manager of a recently established (2011) carpentry business. It employs 4 workers in a conventional business (interview H, 27.11.2015). Our intention was to scan for barriers and opportunities among the diverse enterprises that make up the construction industry.

Further interviews were conducted with enterprises related to the recycling and energetic use of waste wood, that is to waste management (Table 1). One was with the owner of a workshop that employs 5 workers in Bad Feilnbach near Rosenheim. It specializes in the use of recycled timber (interview I, 30.11.2015). The manager of a certified waste management company with its head office in Murnau, which operates nation-wide (9.600 employees) was also interviewed (interview J, 23.11.2015). This is a branch of Veolia Environment S.A., headquartered in Paris. Interview K, 10.12.2015) was conducted with the manager of a medium-sized waste management company based in Munich, which only operates locally and regionally (120 employees). It was founded in 1972 and has an annual absorption capacity of 140,000 tons. In these cases, the interviewers were Sandra Mader and Michael Maier.

Since architects often play important roles in construction design, including creative and innovative applications of materials, we interviewed owner-managers of five architectural firms, about their experiences of cascade and substitution with wood (Table 1). They range in size from a firm with 40 employees located in Gauting (interview A, 18.11.2015), through three firms located in Munich, one with 20 employees (interview B, 17.11.2015), a second with 10 employees (interview C, 07.12.2015), and the other with 7 (interview D, 25.11.2015), to an office with 4 employees located in Augsburg (interview E, 23.11.2015). Our interview partners included a leading expert in LCA in Bavaria, and an architect who combines a professorship at the Technical University of Munich with his architectural practice. Indeed, all of the architects we interviewed have been engaged in promoting the use of wood in construction in recent years, and some have received awards for their designs. The interviews with architects were conducted by Thomas Mandl.

The interviews were not meant to be representative of the industry in any statistical sense. Rather the specific firms were selected because of their engagement with wood, either as construction material, waste material or favored material in architectural design. Thus, the experts who we interviewed needed no convincing of the merits of wood, but could identify the extent to which they valued wood for its cascade and substitution properties, and the opportunities and barriers for their wooden products. Many other firms engaged in construction specialize in the use of other materials, notably concrete, steel, plastics and glass. For them, the issue is one of conversion and substitution to wood as the favored material. This would inevitably involve technical and skill changes in the enterprise, and considerable learning, networking and capacity building. Our research focuses on enterprises that are already capable users of wood and their reactions to calls for cascade use and substitution of wood.

3. Institutional context and framing

Increasing emphasis is placed on wood as a renewable resource and versatile material in Germany, where about one third of the densely populated land is forested and where several policies related to energy and climate change, albeit potentially conflicting, have led to a reassessment of forests and wood. Legislative bodies have placed high expectations on the concept of cascading (cf. Höglmeier et al. 2015). Research institutions, including Bavarian ones, are involved in related research groups, such as the European research project CaReWood, whose aim is to introduce an upgrading concept for recovered solid timber as a source of clean and reliable secondary wooden products for European industry. In addition, the German Advisory Council on Global Change (WBGU) published its report *World in Transition — A Social Contract for Sustainability* (WBGU, 2011), in which it demonstrated the need for a transformation into a climate-friendly world-society, one that is based on a post-fossil economy. Cascade use and substitution of wood are just two of the diverse measures recommended in the WBGU's call for action. They can be clearly related to concepts of transformation and sustainability, and therefore to concepts of innovation, learning and the roles of clusters, particularly in regional development.

Germany's wood use system is framed by sociopolitical expectations. Already in 2002 the German Government agreed in its coalition agreement to adopt the aims of the so-called *Charta für Holz* (Charta for Wood) which proposed an “initiative to increase the wood use in favor of climate, life quality, innovation and

employment." In 2004, a target of increasing per capita wood consumption by 20 percent within ten years was set. Coordination was centralized in the Federal Ministry of Consumer Protection, Food and Agriculture (today the Federal Ministry for Food and Agriculture). This plan favored the material use of wood, especially in construction, but wood use for energetic purposes was also supported (BMELV, 2004). The aim of increasing per capita wood consumption has certainly been advanced though the increased use of wood for energetic purposes was more than anticipated. Nevertheless, resource efficiency and innovative uses of wood have been deliberately propagated over the last decade. They are targeted in Germany's ambitions for the so-called 'bio-economy' (BMBF, 2016). Some of the wood-related actions mentioned in the *Nationale Politikstrategie Bioökonomie* (National Policy Strategy on Bio-economy) are development of emerging markets for innovative wood products or support of the leading-edge cluster bio-economy (BMEL, 2014: 62; 64).

Thus, cascade use of wood and substitution based on wood are the focus of legislation and of research institutions and are related to high expectations. These two forms of an altered wood use are expected to contribute to a more sustainable and climate-friendly society. These two concepts differ in the scope of their application (how to you use a material efficiently? vs. which material to use?) but are entangled when it comes to aims and outcomes, namely coping with climate change through resource efficiency and carbon storage. According to Höglmeier et al. (2015), legislative bodies like the European Commission and the German Federal Environment Ministry have put high expectations into the concept of cascading. Moreover, the WBGU (2011) has emphasized cascade use and substitution as means for resource efficiency and decreasing CO_2 emissions for combating climate change and contributing to a climate-friendly society. It is also a prominent concept in the national policy strategy on bio-economy, in German named *Nationale Politikstrategie Bioökonomie* (BMEL, 2014).

Cascade use is defined as "the use of the same unit of a resource in multiple successional applications" (Höglmeier et al. 2015). Thus, ideally from the beginning, a unit of a resource is planned to be used in a succession of uses and in multiple ways. Resource efficiency and prolonging the time over which carbon is stored within the wood, and thus altogether reducing environmental impacts, are the underlying expected benefits of this concept and its related practices. Thus, the benefit generated by using one unit of wood could be increased by using it in cascades, that is first in multiple successive material applications and in the end energetically (Höglmeier et al. 2015). The same is true for substitution. By substituting wood for other, especially fossil-based, materials, carbon can potentially be stored and the CO_2 balance improved so that environmental impacts are reduced. While cascade use derives benefits from using the same unit of a resource in a multiple and successional way, substitution focuses on the material. When another material is substituted with wood, it would be ideal to incorporate a cascading in that particular wood usage. Whether that is, or will, be feasible and supported in practice remains an open question.

Within Bavaria, the Cluster Forest and Wood not only assembles wood-related industries and companies, but is a Cluster Initiative, a formalized and organized way of promoting economic growth and regional development through the concerted work of cluster firms, government and the research community. As the name 'cluster' implies, additional actors are included, since clusters are "geographic concentrations of interconnected companies, specialized suppliers, service providers, firms in related industries, and associated institutions (e.g., universities, standards agencies, trade associations) in a particular field that compete but also cooperate" (Porter, 2000, p. 15). In this Bavarian cluster, actors range from small companies to large enterprises, with some operating only locally while others are part of global networks, some operate as producers supplying other entities in the chain, while yet others supply design, management or consulting services. Differences in the scale and reach of entities also apply to teaching and research institutions as well as to the associations and governmental institutions assembled in the cluster.

The Cluster Forest and Wood was primarily organized with regional economic performance in mind, and it has operated for many years with no reference to ecological systems or related ideas. As substitution does take place new participants enter the wood use system, and as cascade use is developed the reuse and recycling of materials increases the long term use of materials within the system. The expansion of the wood use system can be interpreted as a sign of building resilience in ecological terms since it implies the substitution of wood for other materials, but calls for substitution and cascade use present the Cluster with new challenges, such as how to encourage and measure innovation. A focus on research and development spending and patenting is less relevant now than attention to material efficiency, life cycle analysis, product certification, and to industry actors previously not considered to be part of the wood products sector. Already, the issue of how to trigger innovation is identified as a problem (interview with Bauer, Cluster Initiative Forest and Wood, 2014) and as a priority for action in *The Agenda Forst und Holz in Bayern 2030*, an action plan based on the latest cluster study, according to Knauf et al. (2016). To realize the potential in a wood using industry like construction requires concerted action by diverse actors, including architects, firms, building inspectors, insurers, and urban planners, many of whom have previously not been thought of as members of the Cluster Forest and Wood. Nevertheless, in conjunction with Bayern Innovative, Cluster Forest and Wood has been energetically assembling such new constellations of activity, for example through "Pro-Holz", a professional marketing campaign, and through their registration with the European cluster program, under which they have "only" achieved the bronze label so far (interview Cluster manager, 2014).

In Germany as a whole, between 2009 and 2014 employment in the Holzbranche (Wood branch) rose from 57,777 to 65,057 (Holzbau Deutschland, 2015). Most (83.3 percent) employees in the Holzbranche work in establishments with less than 10 employees, and only 0.3 percent in firms with over 50 (Holzbau Deutschland, 2015). In this situation it is imperative to facilitate coordination and cooperation in the sector and to offer effective advisory services to upgrade competence in wood construction techniques and assessments. In this regard, the purchase, in 2013, of three wood construction firms – Stephan Holzbau GmbH, Merk Project GmbH and Metsä Wood Merk GmbH (Strabag, 2013) – by the giant German construction firm Züblin can be read as a positive step: Züblin is interested in wood construction.

4. The construction industry

Tackling the German construction industry must be a priority for the energy transition since, in Germany, construction projects are responsible for 60 percent of all waste, 50 percent of non-renewable materials use and 40 percent of primary energy consumption (Bauer et al., 2011, p. 27). There is considerable potential to reduce CO_2 emissions through substitution of wood for other materials, through waste reduction, energy efficiency and carbon storage (Kaufmann, 2009, p. 9). Despite its traditional focus on 'Holzhause' (dwellings built using solid wood or solid timber framing), only 19 percent of the 21,586 buildings completed in Bavaria in 2013 were of this type (Bayerisches Landesamt für Statitik, 2014) and the proportion is much lower in the other German states. Further, in Germany, the total annual new

construction volume can be realized with only a third of the German timber harvest (Wegener, 2011, p. 17). However, German experts forecast over the years 2011–2020 a 20 percent increase in the use of wood as fuel, a 20 percent increase in houses constructed from wood, and a 15 percent increase in the wood use per person (Knauf and Frühwald, 2011a, p. 109). This increased projected demand has placed Germany's forests and construction industry under pressure. Innovations, in particular laminated components which should substitute for steel or more massive pieces of timber, and improved insulation systems for walls, were anticipated and are now on the market (Knauf and Frühwald, 2011b, p. 214; Pollmeier Massivholz GmbH and Co. KG's, 2015; interviews F and I 2015). Further, construction was quickly identified as an important target for energy efficiency and substitution initiatives. The EU established energy efficiency standards in 2002, set new standards in 2010 and, in 2020, only low energy and zero energy houses will be allowed (Tuschinsky, 2015).

Numerous certification systems for sustainable buildings are on offer, such as the BREEAM (UK), or LEED (USA), but these need to be tailored to the particular conditions in each country so, since 2009, the DGNB (Deutsches Gütesiegel Nachhaltiges Bauen) is available for use in Germany (Bauer et al. 2011, p. 162). Buildings made largely from wood generally perform well in LCAs of complete buildings and their materials (König, 2011: 6; Kaufmann & König, 2015, p. 2). This is partly because of the longer lives of such buildings, and the opportunities for rebuilding and alterations, but, especially because, at the end of the life of the structure, wood as a material with a high heat value, can be valued as either recyclable or energetically usable, thus offsetting earlier energy costs associated with its use and giving wood a significant advantage over other materials in an analysis based on cumulative energy use (König, 2011, p. 20).

In 2011, as part of an exhibition in Munich, “Bauen mit Holz” (Building with Wood), funded by the Deutschen Bundesstiftung Umwelt (DBU), a study of the environmental balance of 5 buildings constructed mainly with timber structural elements and 5 comparable conventional buildings constructed largely with non-renewable materials was conducted. This project used and helped to develop the software LEGEP accessible through the data bank Ökobau.dat. The study estimated the renewable and nonrenewable primary energy used, the global warming potential and the acidification potential of each structure. The results indicated substantially (between 36 and 71 percent) less emissions of CO_2 equivalent per square meter of net building area per year over 50 years (König, 2011, p. 22). In 2015, the study was revised to include the CO_2 storage and substitution potential of wood use. This was estimated at between 0.9 and 1.9 tonnes CO_2 equivalent of fossil fuel gas emissions per cubic meter of wood used (Kaufmann & König, 2015, p. 33).

Since 2013, the City of Munich's Münchner Förderprogramms Energiesparen (FES) (Munich Energy Saving Support Program) has operated a CO_2 Bonus Program. The City offers a bonus of 30 cents per kilogram of renewable materials that store CO_2 long term that is used in buildings. To date the scheme covers around 200 projects. To qualify, projects must use wood produced in Germany, within 400 km of Munich or from further afield but with a FSC, PEFC or Naturland certification. While hemp and flax also qualify, tropical timber is not permitted (Pawlitschko, 2015, p. 25). Further, the carbon storage must be coupled with an energy efficiency rating for the building and this makes it hard to achieve with wood construction (interview D 2015, see below).

Institutional support for cascade use and substitution within the construction industry, has changed dramatically over the last decade, as is evident from our review of Bavarian policy initiatives. A diverse array of powerful actors promulgated new regulations, offered incentives, developed new certification systems and technical assessments, and used public forums to advance the cause of wood use within Bavaria. The initiatives are coherent if not completely coordinated. Nevertheless, the effectiveness of this array of policies deserves attention.

5. Responses of construction-related enterprises

The interviews that we conducted with construction industry entrepreneurs revealed that they were appreciative of the combination of new energy efficiency regulations backed by project financing from Kreditanstalt für Wiederaufbau (Development Loan Corporation) which they saw as giving them the opportunity to make their construction projects competitive with conventional ones. If the trend to energy efficiency continues they see real competitive advantages for wooden construction. Three of our interview partners expressed confidence in the market for wooden construction with one declaring it “able to be counted on in the future” (interviews F, G and I 2015). They were knowledgeable and at ease with the new standards: in each of our houses “that is between 130 and 140 square meters in floor area, between 30,000 and 50,000 kg of CO_2 are stored” was clearly a sales point for one of our respondents (interview G 2015). Another, a small carpenter shop enterprise, was certified as a “Meisterhaft Bauen” (Master Builder) which he saw as a new, and therefore as yet not watered down, certification system (interview H 2015). The smaller enterprises were all engaged in the booming market for new construction in southern Bavaria and not with the renovation of older houses. The larger enterprises anticipated large future projects.

However, ‘cascade use’ was a term unknown to some of the entrepreneurs, and they all saw little chance to develop this, particularly in small enterprises, but even in terms of the recycling of timbers through renovation of buildings, simply because of the quality issues. In any case they were each careful with waste and waste wood because these are valuable. Two of our interview partners were open to the use of conventional techniques (interviews F and I). Keeping up with the latest techniques was seen as a burden, and, especially in IT, there was a need for ‘building information modelling’ to ease the problems of making estimates and managing projects within small enterprises (interview I 2015).

There was far less sympathy or active involvement in the association activities from the smaller enterprises than the larger ones. Where our interview partner F, who is chair of the Studiengemeinschaft Holzleimbau (Research Association for Glued Wood Construction) saw engagement as important and called for better marketing of wood products in construction, one of our carpenters (interview H), who has the slogan “Tradition seasoned with innovation” on his website, favors the elimination of nails and screws from construction, views the popularity of certificates and labels as reducing their credibility, and has little faith in the association activities. The producer of finished houses finds that the lobbying that is done by the associations is important: “If you want to achieve something in making new laws, setting new rules or regulations, and articulating new DIN [ISO standards], you must be supported by lobbying and representation of your interests” (interview G 2015). At the same time, he admits that he is not active in any associations because of lack of time.

When asked about the origins of their timber, our interview partners expressed diverse views ranging from “relatively local” timber sources, through “the sawmill at the corner”, to “the Alpine region”. One enterprise relies on certificates of provenance but largely because it is required by the Deutschen Fertighausverband (German Finished House Association) (interview G 2015). The manager of the large timber firm (interview F 2015) pointed out that certification was important, in that 99 percent of all cut wood

available in the EU was PEFC certified. In contrast, interview partner H (2015) argued that the system had little meaning when all wood had the same class. He noted that most wholesalers could not say where their timber came from, and that, because of quality issues, he sourced timber from the local district. He contended that his customers were not impressed by labels and certificates but by the competence of his craftsmen. The producer of finished houses confirmed this perspective when he declared:

Well, where precisely the spruce comes from, whether it comes from Bavaria or Austria, that I cannot guarantee, but we can guarantee that it was harvested at 1100 m or more above sea level. There, growth is simply slower, it is better to work with, (…), but it is, in any case, from the Alpine Region and not some cheaply cut wood from somewhere in Belarus. (interview G 2015).

This statement highlights both the insistence on quality among our interview partners, and the mistrust we encountered: many of the new regulations and certification systems were seen as out-of-step with the realities of wood construction in Bavaria. EU-wide certification of timber meant that almost all available timber was certified to the EU requirements making the certification redundant, and obscuring the role of timber quality in supply contracts. Our interview partners regarded 'sustainability' as a fashionable idea, and as an opportunity to sell high quality products to consumers, but one that was already actively pursued in the industry (interview G 2015) albeit in diverse ways due to the diverse enterprises and products that the construction industry produced. They were wary of those who use environmental thinking and sustainability as a slogan (interview H 2015) and perceived the real constraints on the achievement of climate goals through innovation in construction industry as lying in consumer preferences for cheaper housing with lifestyle amenities rather than more expensive, higher quality, hand crafted buildings that met new energy standards. As one interviewee phrased it, consumers preferred to have a window in their north-facing wall rather than have an effectively insulated wall there (interview G 2015).

6. Responses of waste wood-related enterprises

The term 'waste wood' is used for all lumber and engineered wood (wood-based materials), whose end as a product is reached (Meinlschmidt, Berthold, & Brisemeister, 2013, p. 154). However, 'waste wood' can be a very diverse wood pile with products and materials of different composition and contamination. Harmful substances in waste wood result from wood preservatives, paints, coatings and components of wood-based materials like binders and hardeners (LfU Bayern, 2012). The organized use of waste wood is a central link of the cascade use (Hammerl, Friedrich, Borchert, & Schumann, 2012, pp. 37–40).

Waste wood can be available as a secondary raw material for material or energetic utilization. The legally binding obligation for use and disposal management of waste wood is defined by the Closed Substances Cycle Waste Management Act (KrWG) in Germany. The idea of reuse is embedded in this legal framework, which follows EU regulation. In order to achieve the link of waste accumulation to availability as secondary raw material the waste needs to be collected, sorted and pre-processed before it goes to the end user. This work is done by waste management companies like the two whose managers were interviewed for this study (Table 1).

According to the Waste Wood Ordinance (Altholzverordnung - AltholzV) waste wood is classified into four plus one special categories, depending on the level of pollutants load. The special category is for heavily polluted waste wood that needs to be disposed of. The actual categories range – depending on quality and amount of additional substances – from A I to A IV. In terms of these categories a use as a secondary raw material is conditionally possible, although the best category for any further use is the first one (basically natural, untreated and only mechanically processed wood). In general, waste wood of the categories I to III is considered not harmful in contrast to the category A IV. However, requirements for any re-use of wood of category I to III do exist and are clearly expressed in the Waste Wood Ordinance. With this regulation the legal framework for waste wood management is set and allows for the availability of waste wood as a secondary raw material for the material and energetic utilization.

In practice, the sorting according to these four categories is rarely followed. In the interviewed companies the practice is that one (Interview J 2015) differentiates between two categories, and the other (Interview K 2015) works with three categories. In general, for each original category chemical analysis of foreign substances is possible but costly, and might only be applied if a certain quantity is given so that it makes sense economically for the waste producer, who needs to bring evidence about non-contamination or type of contamination (Interviews J and K 2015). Costs for the chemical analysis plus the removal should be far lower than the money gained for the waste wood. Eventually this means also time and organization expenditure. Our interview partners stated that this would only make sense if it is financially beneficial.

In the end, the waste management company sorts at the waste production site according to legal presumption (interviews J and K 2015). The proper dividing of the wood into the given categories is not easy, so that if there is uncertainty the next higher category is chosen (interviews J and K 2015). Waste management companies bundle waste wood quantities, relying thereby on quality that is provided by the waste producer (interview J 2015), as well as selling and transferring certain qualities, making their sorting correspond to the quality demanded by the end-user (interview K 2015). Thus, although the waste management is embedded in a set legal framework, it is the demand on the waste production as well as the demand from the end-user that in the end shapes the practice of everyday-business within waste management companies.

Regarding the quantity of waste wood in Bavaria as well as in Germany the applied methods of gathering data vary which also results in heterogeneous numbers (cf. Hammerl et al. 2012, pp. 37–40). The total quantity of waste wood consists of the quantity captured by commercial waste wood treatment companies plus the amount accrued in private households, which is used directly for material or energetic purposes and which does not enter the waste wood cycle. Therefore, for Bavaria, Hammerl et al. (2012) extrapolate 1.25 million t atro (ton absolutely dry) waste wood occurrence (equivalent to 100 kg per capita and year), of which 1.07 million tons atro are captured by commercial treatment companies. Disposal of waste wood in Germany is marginal (Mantau and Weimar, 2008) and therefore, waste wood is being made available either for material or energetic purposes. This means a waste wood market exists with collection, treatment, trade and ultimately prices.

In Bavaria, most waste wood is used thermally in big steam cogeneration plants and in terms of material use, it is mainly applied in the production of wood-based material like chipboards (Hammerl et al. 2012, pp. 37–40; interviews J and K 2015). If the export of waste wood is not considered, in Bavaria three quarters of the commercially captured waste wood is used thermally and almost a quarter materially (Hammerl et al. 2012, pp. 37–40; interviews J and K 2015). Generally, this pattern also applies for Germany as a whole (Mantau and Weimar, 2008). This underlines the efforts of Germany's government towards an energy transition, where biomass is considered the most important and also the most versatile renewable energy source. Furthermore, this means that single-stage or short cascades (wood of a product after its first life cycle is used for energy recovery) are dominant.

However, considering increased resource prices as well as the socio-political expectations to cope with climate change and resource efficiency, there is greater demand and pressure to use waste wood more materially. Consequently, material users have to compete more and more for waste wood against biomass power plants (BAV, 2012). This competition is certainly noted by the regionally operating, but not the nationally operating enterprise (interviews J and K 2015).

On the other hand, the prices for waste wood have been constantly increasing since the mid-1990s (cf. Müller-Langer, Schneider, Witt, & Thrän, 2016; and Bauer et al. 2011). This trend is confirmed by the rising prices within South Germany in the last ten years due to an increase market for biomass (Hammerl et al. 2012, pp. 37–40). Increased demand and also prices for waste wood might be an explanation for an increased turnover of waste wood, which the regionally operating enterprise is aiming for: from currently 25.000 tons–35.000 tons in the following year (interview M 2015). In contrast, the enterprise that operates nation-wide (with a nationally turnover of about 200,000 tons of waste wood in 2015), does not favor waste wood as a leading business, perceiving its work as supplying the big plants, such as AR Recycling, the largest provider of biomass within Germany, which it expects to take the lead in new processing and treatment techniques and in offering resources (interview J 2015). The market seems to be settled and although wood is a promising material, the interview results point towards a stable market structure. In summary, Hammerl et al. (2012: 40) predict that neither the market nor the prices will decrease in the next years and that it is unlikely that the waste wood market structure will change significantly in terms of the volume of waste wood or the number of big players in the foreseeable future.

'Innovation' is crucial in the language of climate change and resource-related policies. Especially in the national strategies on bio-economy (policy and research) innovation is constantly mentioned and propagated as the key to economic growth and international competitiveness (BMBF, 2010; BMEL, 2014). In both interviews, wood as a material was assigned great possibilities and the field of waste wood and waste management in general was declared to have great potential for innovation, because technology is playing a big role. Thus, innovation in this field is interpreted in terms of technology development, with a focus on technical processes like the detection of substances and sorting of waste wood. Near infrared (NIR) spectroscopy, the newest sorting technology, could support material use and cascade use of wood (Meinlschmidt et al. 2013), however, for medium-sized companies, this is only profitable with a higher waste wood quantity (interview K 2015). For a higher material use of waste wood and therefore a more fully implemented cascade use, more unpolluted or shallow treated wood, where foreign substances can be removed with known technology, would be necessary. Further, from the viewpoints of the interviewed companies, economic incentives are necessary or could be helpful to promote cascade use and a greater material use (interviews J and K 2015). However, a sales market needs to be ensured (interview J 2015).

In the end, the waste wood management companies have the potential to drive innovation at least in terms of processing technology if a certain quantity and predefined quality can be assured. This means that the initial product needs to be free of pollutants as much as possible. If more material use and consequently cascade use is aimed for then it also needs certain markets afterwards, which the waste management companies cannot influence. This is where product innovation would come into play, and where the Bavarian Cluster Initiative Forest and Wood could be a key actor. The interviewed waste management companies have no contact to the Initiative and in fact, they do not consider themselves to be part of the wood industry. Product innovation with respect to waste wood seems to be an open question with an unforeseeable future for now.

Niche markets might play a role. One waste wood management company is specialized on the recovery of Bavarian "historical" waste wood and re-uses it for unique furniture manufacturing (interview I 2016). This carpentry shop owner remarked that the recycling branch of the industry was currently working at its peak and that this might last no more than three years (interview I 2015). For him the only valuable recycled wood was that which was more than 20 years old, hand cut and largely free from holes and marks. For a change in market and market structure there would need to be innovative activity on a bigger scale. Huber (2000), contributing to the 'industrial ecology' debate (transformation of traditional industrial structures to environmentally adapted ones), even argues, that it is necessary to develop 'system innovations', which go beyond special process improvements or single product innovations.

7. Responses of architects

The architects we interviewed see the wood construction tradition in Bavaria, the research into wood at the Technical University Munich (TUM), and the architectural training in wood at the TUM as great opportunities (interviews A, B and D 2015). This constellation is bolstered by interactions with technical centers for wood construction in Vorarlberg, Austria, and by the ProHolz-Bayern initiative of the Cluster Intiative Forest und Wood Bavaria. Two of the architects we interviewed are active in these circles and they report efforts to broaden the circle. The Bund Deutscher Architekten (Union of German Architects) and ProHolz are sponsoring an advisory service for energy efficiency and sustainability at the Architekten-kammer Bayern (Chamber of Bavarian Architects) (interviews D and E 2015). Interviews with architects active in Bavaria indicated understanding of the advantages of wood in construction but also barriers to increased use. The architects we spoke with all agreed that wood is a beautiful material, which is assessed by clients as offering a special spatial feel and living quality, along with health benefits. They saw this as the most attractive aspect of building in wood. They appreciated wood's insulation (lighter and thinner walls for the same insulation value, thus saving space and money) and flexibility (ease of renovation) advantages, which combine to offset wood's initially unattractive cost (especially for cladding, the building standards for which have just been increased).

Each district within Bavaria has its own regulations which may or may not facilitate or promote wood use. The architects regard Bavaria as having too many regulations that constrain wood construction, especially what they see as out-of-date building codes, and variations specific to each district and city. For example, in Munich, high standards regarding soundproofing, fire protection, and the use of volatile organic compounds (VOCs) in wood composites due to health risks, constrain wood use (interviews A, B and C 2015). Several of the architects interviewed noted that air conditioning units, long periods without occupants to let the danger pass, or alternative materials were necessary when using composites in construction in order to reduce VOC levels to the required standard. Despite its CO_2 Bonus Program, the City is regarded by those architects who are eager to advance wood construction as not doing enough to support the transition, of which they are well aware: its building codes are too strict and uncompromising; its construction office unsympathetic; and, even in Munich, few architects realize that the City's CO_2 Bonus Program exists. One respondent (interview B 2015) contrasted the strict Bavarian building laws with Baden-Württemberg's more flexible official

approach.

Further, the City of Munich's two building societies, the GWG (Städtische Wohnungsgesellschaft München mbH with 28,000 apartments) and the GEWOFAG (Gemeinnützige Wohnungsfürsorge AG with 35,000 apartments), both of which have promoted some wood construction projects in recent years, seem to have discontinued this experimentation, a reversion to their apparently 'anti-wood' construction policies which emerged after disappointing experiences from building cheaply in wood in the 1980s and 1990s (interview C 2015). This policy preference has been reinforced by experiences with VOC levels in newly built wooden school buildings.

Life cycle analyses may demonstrate the merits of substitution, especially with regard to reducing CO_2 emissions, but they are not required, are costly, no subsidies are available, there are few experts available, and so they are seldom completed, except, as in the cases of two of the architects we interviewed (interviews D and E 2015), for research and learning purposes. Moreover, the estimates rely on detailed surface area and cladding specifications, which may dominate the results (interview D 2015). It is, for example, possible to achieve a surplus energy house rating by using enormous quantities of insulation from non-renewable resources (interview A 2015). Our interview partners also mentioned what they perceived as lobbying by award-winning firms at work with solid (concrete, steel, glass) construction, and climate-related specifications in the DGNB's criteria that could not be met by wood construction (interview D 2015). They asserted that the regulations, subventions and awards were constructed to favor what they insinuated was a solid construction-cement-and-brick lobby. Nevertheless, they saw building costs, rather than environmental impacts, as the deciding criterion in construction decisions.

When compared with solid construction, timber construction allows greater recourse to prefabrication, and thus reduced assembly time on site (Kaufmann, 2011: 45; Kolb, 2007, p. 25), but, in practice, poor communication among architects, prefabrication and construction firms often leads to limited realization of this theoretical advantage. However, studies find that the competitive bidding process characteristic of this industry and enshrined in German law is an important source of time delays and coordination problems among architects and construction firms, and thus actually results in longer planning phases (Hochschule Luzern, 2015; DBU, 2012: 162). Better co-ordination is now recommended and is the subject of studies designed to improve it through 'integrated planning'. Moreover, since time delays are significant in cost structures, the current tendering processes tend to act against building with wood. Unless wood construction is stipulated in the contracts, it is hard to construct a competitive tender, largely because of the costs of the long planning phase.

Nevertheless, the cost structures are complicated. While the general rule is that wood construction is 5 percent more expensive than solid construction (interview D 2015), due to the more valuable material and the higher labor, house technical, and planning costs which offset the savings from shorter assembly times (interviews B and E 2015), effective project planning can result in price competitive wood construction projects. Cost reduction is therefore a matter of considerable importance in wood construction. Whether this should be achieved through such measures as concentration in the industry to produce more integrated wood construction firms, through integrated planning and contracts specifying wood construction as required, or through imposition of extra costs for solid construction to penalize CO_2 emissions remained a matter or controversy among the architects interviewed.

8. Conclusion

Our aim is to investigate the responses of industry participants to the calls for cascade use of wood and substitution as part of a transformation to a climate-friendly society. It can be expected that Bavaria's architects, wood waste collectors, and wood workers should, as the ones interviewed for this research certainly do, embrace cascade use of timber, a move to energy efficient housing, policies designed to reduce deforestation, innovate new wood products, and storage of carbon in wood as acts to reduce carbon emissions and not simply as marketing strategies. They genuinely expressed their love of wood and their association of this material with sustainability goals and practices.

However, quality issues and the size of enterprise cut across the responses to calls for making the great transformation. Our interview partners in construction will adopt new materials and methods accepted when useful, and, realistically, seek better project planning and new financing models to allow them to be cost competitive. Quality and price issues are perceived as restricting prospects for further cascade use in the industry. The high price of energy, including wood energy, is regarded as a barrier to any further development of cascade use. Respondents who worked in small enterprises expressed their mistrust of the regulatory approach, and especially the preference given to certification by regulators seeking transformation. They want new marketing initiatives emphasizing craft work and quality and view the reliance on timber certification as a practice favoring larger enterprises. Concern was expressed to us that, in fact, the current energy efficiency regulations, a bewildering array of local, sometimes out-of-date, building codes, and prejudices against wood construction for public buildings combine to conspire against wood construction. How to achieve cost reductions for wood construction relative to other materials remains an important concern. Various answers are being discussed in the industry, including corporate concentration to produce more integrated wood construction firms, development of integrated project planning, contracts requiring wood construction, and imposition of extra costs for solid construction to penalize CO_2 emissions.

The regulations concerning waste wood have resulted in a well-developed market and industry structure, but effectively combine with other factors, and notably the energetic use of waste wood in Bavaria as well as the widespread contamination of waste wood, to constrain further development of cascade use. To further open the potential for cascade use will require new regulations limiting wood treatments, a development that would hamper innovations related to laminated and composite products.

There is an enormous amount of activity in Bavaria to advance the transformation goals set by the WBGU, and this activity is concerted. Studies justifying cascade use and substitution have been published. Diverse institutions, ranging from the City of Munich, through the Cluster Forest and Wood, the Technical University of Munich, and the Union of Architects, to the Ministry for the Environment are active, as is evident from our research. Energy efficiency has been targeted as a goal through such policies as Munich's CO_2 Bonus program. Demonstration projects such as the Building with Wood exhibition in Munich, 2011, have generated publicity and awareness in the society at large, as well as the industry. Moreover, this is a reflective process as is evidenced by the funding of this particular study.

This paper draws attention to the tensions and pressures emerging over new technical systems that are expected to drive the energy transformation, tensions that parallel the conflicts arising over new forest socio-natures (e.g. De Koning et al. 2014; Mansfield et al. 2015) and the tensions between "bottom-line realities" and "strong environmental motivations" among SME owners

apprehended in earlier studies on opportunities and constraints to pro-environment actions among SMEs (North 2016). The most disturbing finding from our research is that architectural firms actively pursuing wood construction note numerous problems that they have encountered as catalytic change agents. However, we note that the fine-tuning of policies to effect the transformation is a work in progress, and that any such fine-tuning must pay attention to the economic organization and market realities of the firms which are expected to implement cascade use and substitution.

Acknowledgements

This paper is part of a Bavarian government-funded research project 'Wood future or forest track: Opportunities, barriers and compromises in changing the use of wood as a contribution to social transformation,' which is part of an interdisciplinary research group 'Fit for Change.'

We thank Lisa Bauer, Sandra Mader, Michael Maier, Heidi Majewski, and Thomas Mandl for their work interviewing experts from the Bavarian industry.

Legal norms

Gesetz zur Förderung der Kreislaufwirtschaft und Sicherung der umweltverträglichen Bewirtschaftung von Abfällen (Kreislaufwirtschaftsgesetz – KrWG) from 24.02.2012.

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